

# Announcements

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## Homework for tomorrow...

Ch. 23, Probs. 10, 12, & 52

22.30: a) double-slit as  $\Delta y$  is the same

b)  $1.5 \times 10^{-4}$  m

22.32:  $4.0 \times 10^{-4}$  m

22.49:  $16^\circ$

## □ Office hours...

MW 10-11 am

TR 9-10 am

F 12-1 pm

## □ Tutorial Learning Center (TLC) hours:

MTWR 8-6 pm

F 8-11 am, 2-5 pm

Su 1-5 pm

# Chapter 23

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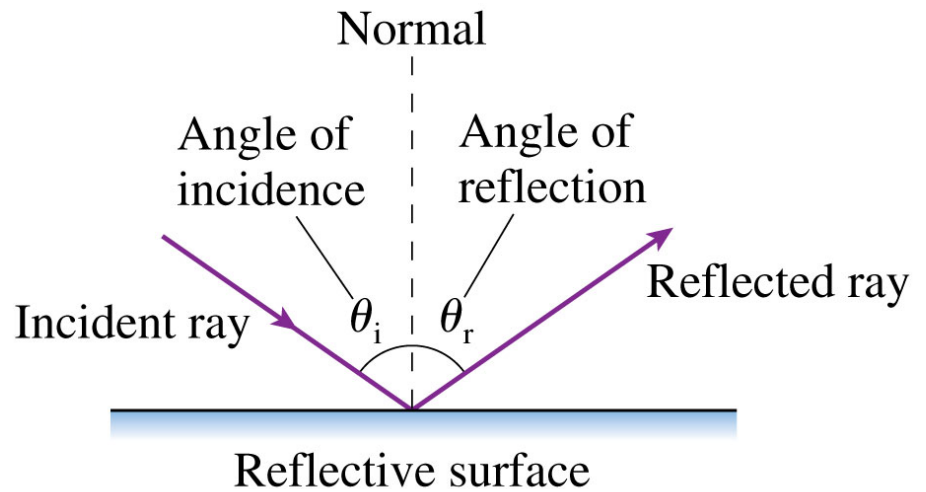
## Ray Optics *(Reflection & Refraction)*

## *Last time...*

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- The *Law of Reflection* is...

$$\theta_i = \theta_r$$

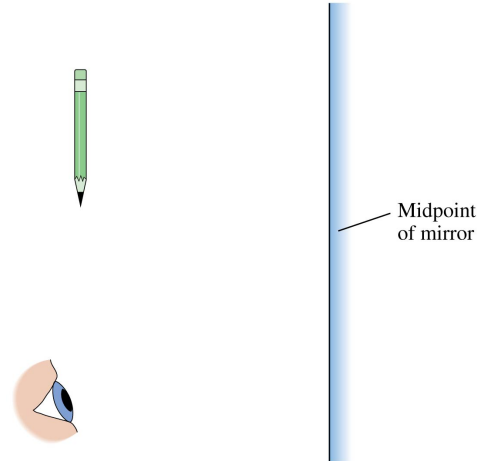


## Quiz Question 1

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You are looking at the image of a pencil in a mirror.

What do you see in the mirror if the top half of the mirror is covered with a piece of dark paper?



1. The full image of the pencil.
2. The top half only of the pencil.
3. The bottom half only of the pencil.
4. No pencil, only the paper.

## 23.3: Refraction

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Two things happen when a light ray is incident on a *smooth* boundary between two transparent materials:

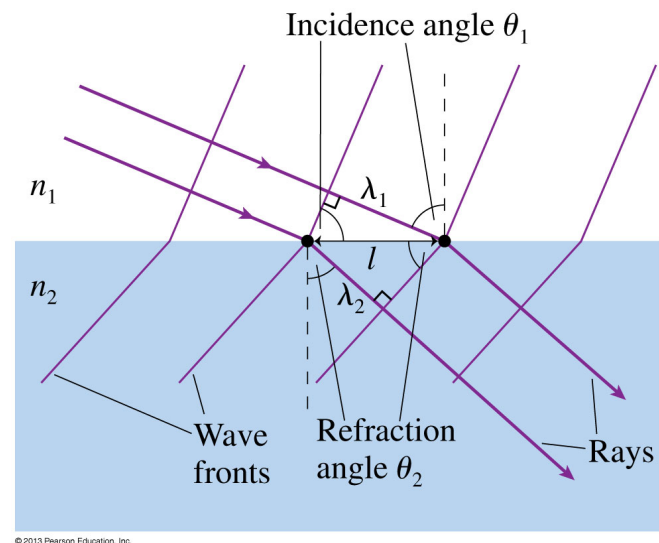
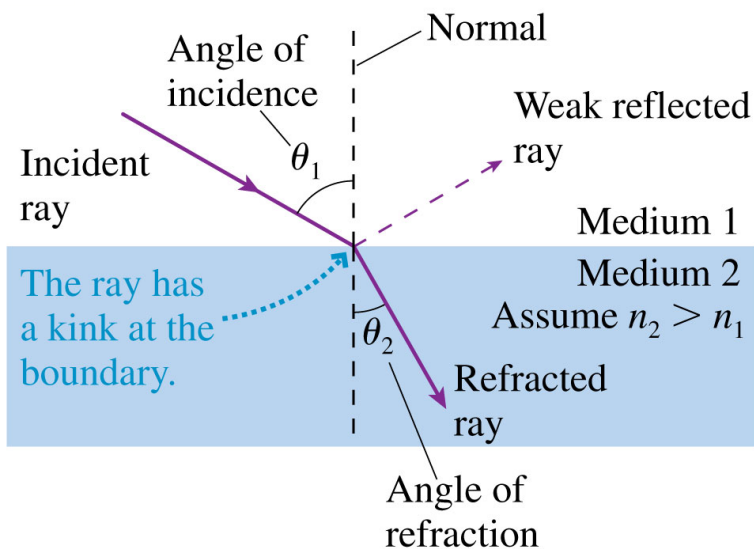


1. Part of the light *reflects* from the boundary, obeying the *law of reflection*.
2. Part of the light continues into the second medium. The transmission of light from one medium to another, but with a change in direction, is called *refraction*.

## 23.3: Refraction

A ray refracts between medium 1 and medium 2, having *indices of refraction*  $n_1$  and  $n_2$  and *ray angles*  $\theta_1$  and  $\theta_2$  in the two media..

What is Snell's Law?

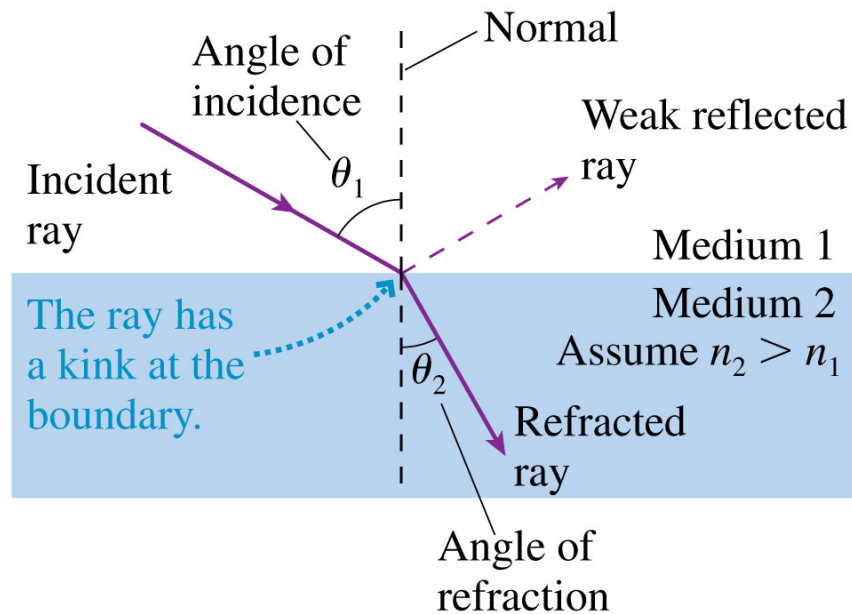


## 23.3: Refraction

A ray refracts between medium 1 and medium 2, having *indices of refraction*  $n_1$  and  $n_2$  and *ray angles*  $\theta_1$  and  $\theta_2$  in the two media..

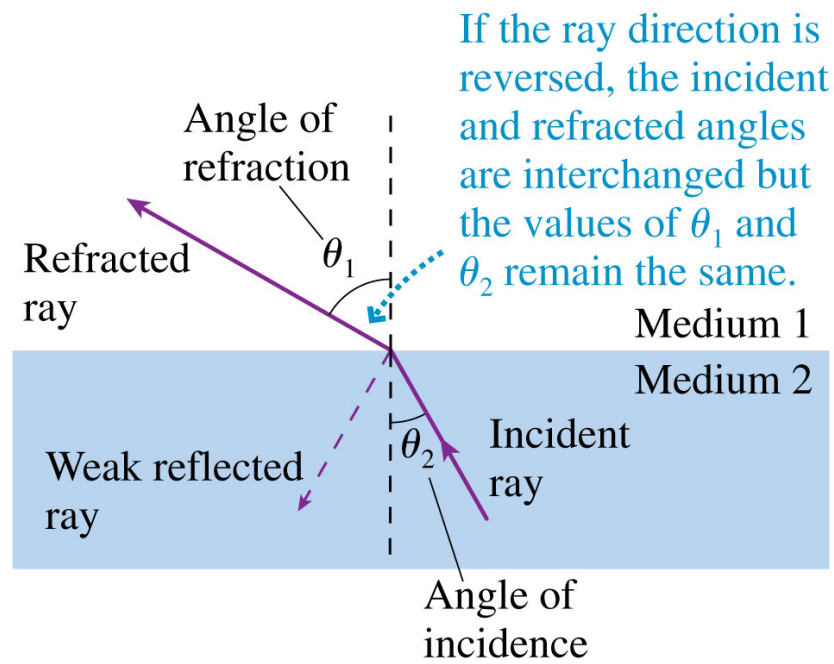
What is Snell's Law?

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$



## 23.3: Refraction

What if the ray direction is reversed?



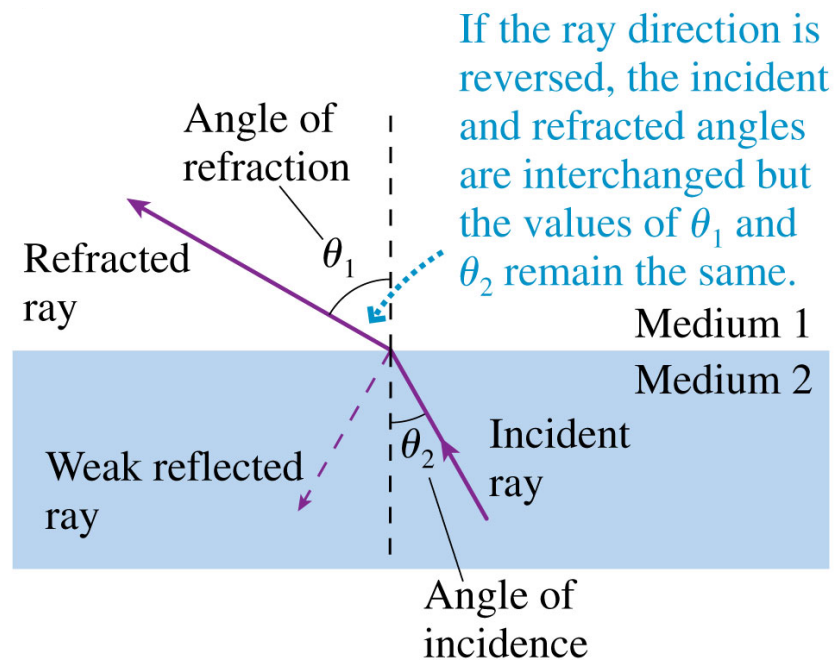


## 23.3: Refraction

What if the ray direction is reversed?

Snell's Law is still obeyed!

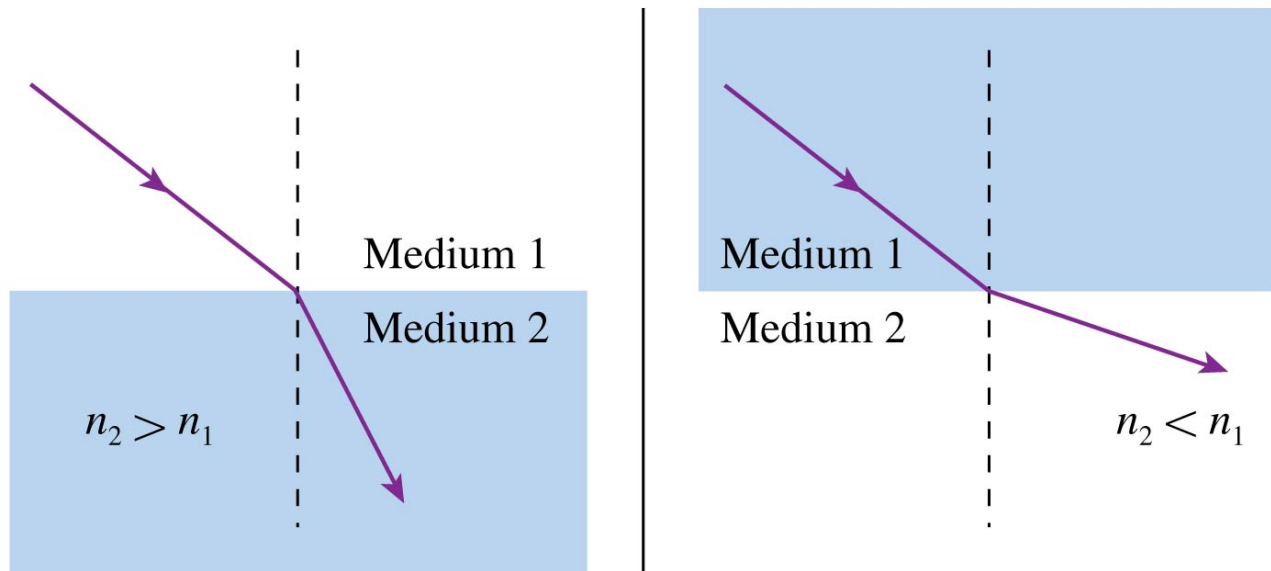
$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$



## 23.3: Refraction

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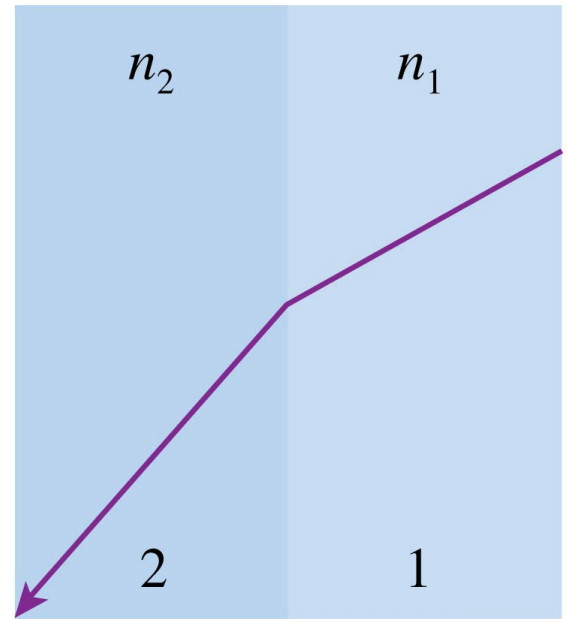
- When a ray is transmitted into a material with a higher index of refraction, it bends *toward* the normal.
- When a ray is transmitted into a material with a lower index of refraction, it bends *away from* the normal.



## Quiz Question 2

A laser beam passing from medium 1 to medium 2 is refracted as shown.

Which is true?

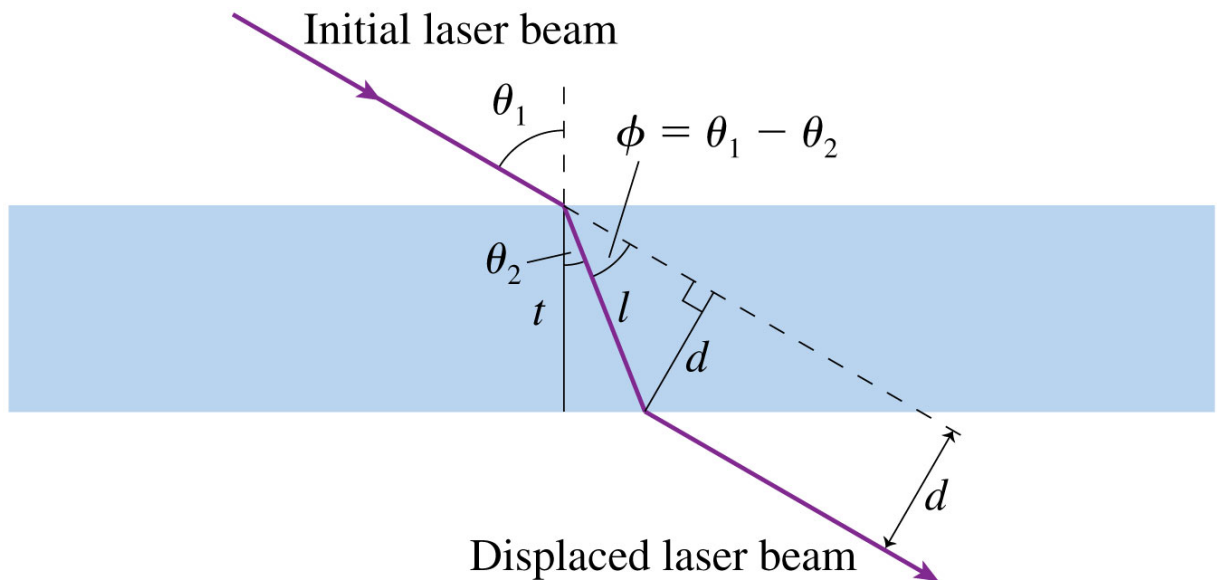


1.  $n_1 < n_2$ .
2.  $n_1 > n_2$ .
3. There's not enough information to compare  $n_1$  and  $n_2$ .

## i.e. 23.3: Deflecting a laser beam

A laser beam is aimed at a 1.0 cm thick sheet of glass at an angle  $30^\circ$  above the glass.

- What is the laser beam's direction of travel in the glass?
- What is its direction in the air on the other side?
- By what distance is the laser beam displaced?

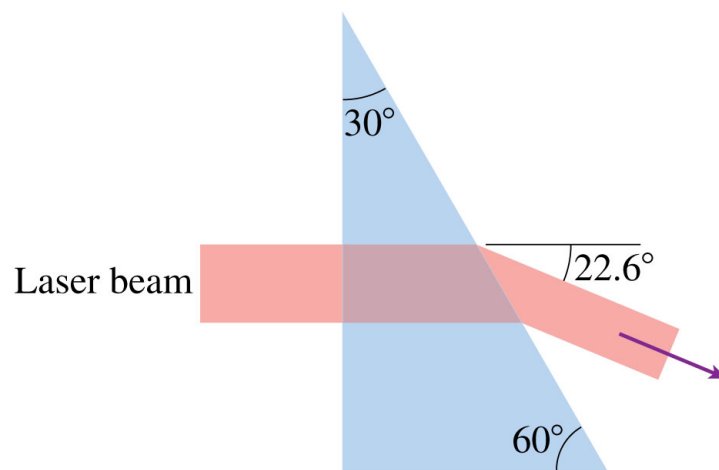


i.e. 23.4:

## Measuring the index of refraction

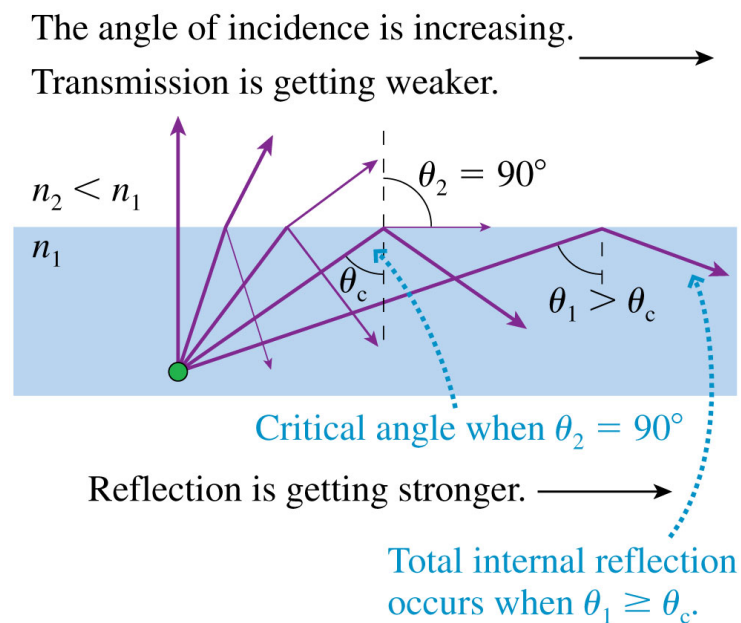
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The figure below shows a laser beam deflected by a  $30^\circ$ - $60^\circ$ - $90^\circ$  prism. What is the prism's index of refraction?



# Total Internal Reflection...

- When a ray is transmitted into a material with a lower index of refraction, it bends *away from* the normal.
- There exists a *critical angle*,  $\theta_c$ , where one gets *zero* refraction!
- What is  $\theta_c$ ?



# Total Internal Reflection...

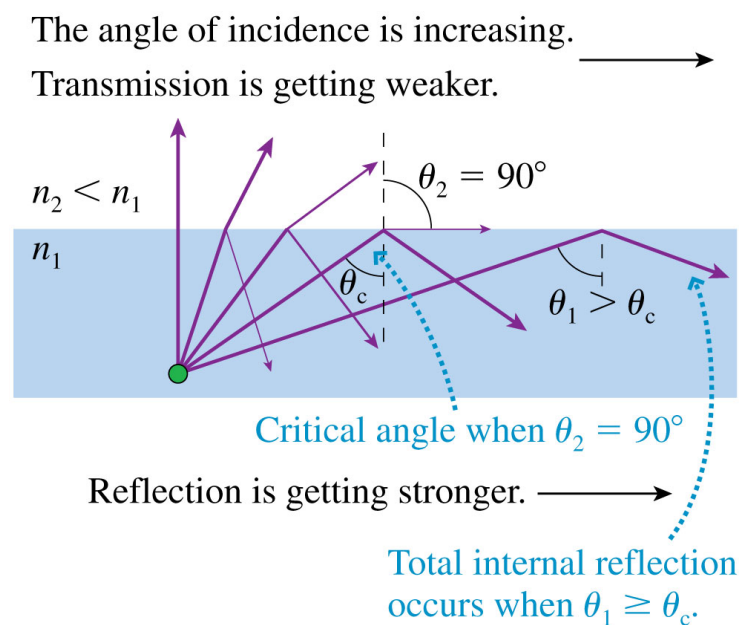
- When a ray is transmitted into a material with a lower index of refraction, it bends *away from* the normal.
- There exists a *critical angle*,  $\theta_c$ , where one gets *zero* refraction!
- What is  $\theta_c$ ?

$$\theta_c = \sin^{-1} \left( \frac{n_2}{n_1} \right)$$

Notice:

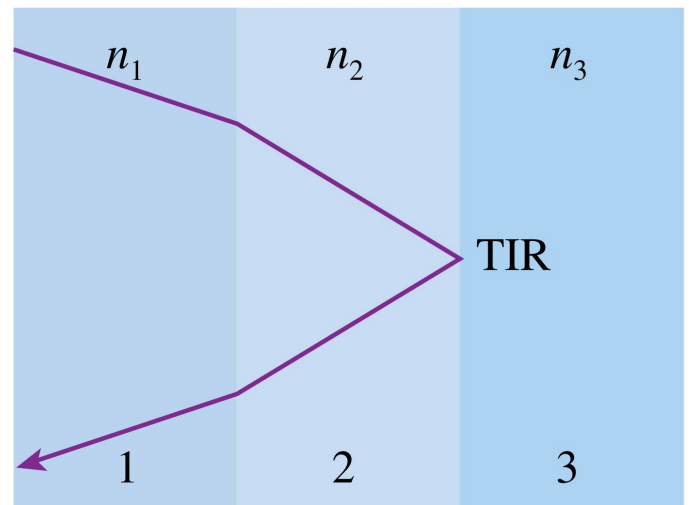
As  $\theta_1$  *increases*...

- $\theta_2$  approaches  $90^\circ$ .
- fraction of *transmitted* light energy *decreases*.
- fraction of *reflected* light energy *increases*.



## Quiz Question 3

A laser beam undergoes two refractions plus total internal reflection at the interface between medium 2 and medium 3. Which is true?



1.  $n_1 < n_3$ .
2.  $n_1 > n_3$ .
3. There's not enough information to compare  $n_1$  and  $n_3$ .



i.e. 23.5:

## Total internal reflection

A light bulb is set in the bottom of a 3.0 m deep swimming pool.

What is the diameter of the circle of light seen on the water's surface from above?

